Frankford Arsenal
Bridge and Tacony Sts.
Philadlephia
Philadelphia County
Pennsylvania

HAER PA-74

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

PHOTOGRAPHS

Historic American Engineering Record
National Park Service
Department of the Interior
Washington, D.C. 20240

HISTORIC AMERICAN ENIGNEERING RECORD

PA-74

FRANKFORD ARSENAL

Date: Various periods of construction starting in 1816 and continuing up into the 20th century.

Location: Bridge and Tacony Sts. Philadelphia, Philadelphia County, Pennsylvania.

Owner: United States Government

Significance: Starting in 1816 as a storage facility, Frankford Arsenal grew into the United States most well known ordnance manufacturers, specializing in small arms munitions. The arsenal was closed down in the mid-1970's.

Transmitted by: Dan Clement, 1984. For more information on the Frankford Arsenal see Historical and Archeological Survey of Frankford Arsenal Philadelphi, Pennsylvania, prepared for the Department of the Army, Baltimore District Corps of Engineers, Baltimore Maryland by John Milner Associates, 309 North MAtlock St. West Chester, Pennsylvania.

Addendum to:
Frankford Arsenal
South of Tacony Street between Bridge Street and
the tracks of the former Pennsylvania Railroad
Philadelphia
Philadelphia County
Pennsylvania

HAER No. PA-74

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
Mid-Atlantic Regional Office
National Park Service
U. S. Department of the Interior
Philadelphia, Pennsylvania 19106

HAER PA, 51-PHILA, 693-

Location: South of Tacony Street between Bridge Street and the tracks of the former Pennsylvania Railroad, Philadelphia, Philadelphia County, Pennsylvania.

UTM: NW: E494120 N4428480
NE: E494780 N4428750
SE: E495120 N4428260
SW: E494190 N4428140
Quad: Frankford

Date of Construction: 1816-1976

Present Owner: Arsenal Associates
P.O. Box 26767
Elkins Park, PA 19117

Present Use: Vacant, Industrial, Offices

Significance: Established in 1816, the Frankford Arsenal served for three decades as a depot for the storage and repair of arms, accoutrements, and ammunition for the United States Army. From 1849 to 1976 the Arsenal served as the nation's principal developer and manufacturer of small arms and artillery munitions. Frankford Arsenal pioneered mechanized production of munitions and developed numerous important innovations in ordnance and precision instruments. Technological innovations introduced at Frankford Arsenal made important contributions to the mechanization of American industry and the implementation of interchangability and mass production techniques.

Project Information: This documentation was undertaken in August 1988 in accordance with the Memorandum of Agreement between the General Services Administration, the Pennsylvania State Historic Preservation Officer, and the Advisory Council on Historic Preservation as a mitigative measure prior to the demolition of several buildings at Frankford Arsenal.

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The built environment that presently defines the Frankford Arsenal is a sprawling collection of buildings and structures associated, in varying degrees, with the technological innovations developed at the site. Founded as an ammunition depot and repair shop in 1816 by the United States Army's fledgling Ordnance Department, Frankford developed into the most important manufacturer of military small arms ammunition in the United States. The Arsenal also played a leading role in the research and development of precision instruments and production line manufacturing techniques. The post's history reflects cycles of war and peace, and research stemming from military necessity and peacetime research and development.

The Ordnance Department, established in 1812, initially functioned largely as the federal agency responsible for the procurement, repair, and storage of military weapons and munitions.[1] In 1815, following an administrative reorganization, the Department began to establish arsenals for the storage of weapons and munitions in various parts of the country.[2]

The Philadelphia area was an obvious candidate for one of the new arsenals. As a river seaport, located at the head of a long, narrow bay, the city could be easily defended in time of war. Philadelphia's role as the nation's leading seaport, with well-established mercantile connections to other countries, and its leading position within the nation's growing powder industry, also made it an attractive location for an ordnance installation.[3]

Ordnance Department representatives searched for a suitable site for the new arsenal in Oxford Township, near Frankford Creek, for more than five months in 1814. In September, 1815, the government took an option on a fifteen-acre parcel one half-mile from Bridge Street (known as Ferry Street until 1811) called the Prentiss (Prentice) land. The tract cost less than land closer to the Delaware River, which sold for as much as five dollars per foot, and consequently had only limited access to the water.[4] In May 1816 the government purchased a second tract from Frederick Fraley. The two parcels totalled slightly more than twenty acres.[5]

Frankford Arsenal opened in May 1816 as an issuing depot for the storage and repair of ordnance. Construction work constituted the principal activity at the new depot until 1818. Soldiers performed most of the basic work, except the masonry, and erected temporary structures for two officers and twenty-one enlisted men, as well as conducting the post's limited military functions.[6]

The first permanent structure constructed at Frankford Arsenal was a wharf, located on Frankford Creek at the western edge of the property.[7] The wharf enabled barges and boats to deliver stone and other building

materials to the site. Like other depots established in the early days of the Ordnance Department, the grounds of Frankford Arsenal were developed around an open square. This plan permitted all domestic quarters and warehouse buildings to relate to a planted green space. The buildings that enclosed this open area, all constructed of stone and "rough cast," consisted of three officer's quarters (Buildings 1, 2 and 3), the Arsenal (Building 14), barracks, shops, storehouses, a saddler's shop, a mess hall, and a kitchen.

Among the first buildings completed were a small four-room officer's quarters (part of Building 1) and a barracks (no longer extant). In 1817, following the completion of these housing projects, the Arsenal's storehouse (Building 14) was begun.[8] Intended as the grandest building on the post, the storehouse was constructed of local gneiss. A magazine, located between the square and the river, apart from the other buildings, was completed in 1819. Despite these building efforts the development of the square remained incomplete until 1823, principally due to a shortage of funds.[9]

In 1821, funds diverted from other construction projects permitted completion of a much-needed gun-carriage house (Building 106).[10] A continued lack of funds caused the construction of additional permanent storage facilities to be postponed.

In 1835, following the reestablishment of the Ordnance Department after an eleven-year period during which the department had been absorbed into the Artillery, a major construction effort began at Frankford Arsenal. The erection of the largest and most pretentious building yet constructed at the Arsenal, the East Storehouse (Building 5), defined the eastern border of a second square. The first brick building constructed at the Arsenal, this three-story storehouse incorporated a separate stair tower and other safety measures. The second square, landscaped in a similar fashion to the first, was planted with trees obtained from local nurseries.[11]

The East Storehouse occupied a location at the eastern edge of the Arsenal property, immediately adjacent to Bomford Road, a forty-foot right-of-way shared by the depot and the farm owner to the east. After construction of a magazine south of the Storehouse, only twenty feet from the property line, it became evident that the Arsenal required additional land. The original grounds covered less than the minimum twenty-five acres mandated for Ordnance depots, and much of the southwestern portion of the site was marshy and suitable only for an exceptionally well-built magazine.

In 1836, the government purchased a three-acre lot adjacent to the post's eastern border.[12] This land increased the security of the new

magazine and the principal storage facilities, and provided room for the proofing of powder.

Prior to the 1840s, Frankford Arsenal had functioned solely as a repair and storage depot. In the early 1840s, however, machinery for the manufacture of percussion caps and compressing machines, capable of producing 40,000 lead balls in a ten-hour day, was introduced at the Arsenal.[13] These developments presaged a new involvement in research, design, and manufacture. After 1848, the Ordnance Department, which heretofore had only slowly broken from the craft tradition, took a decided turn toward mechanization and standardization, permitting production of large uniform quantities of munitions.

Percussion caps, an essential technological step in the development of metallic cartridges, and therefore crucial to the perfection of breechloading small arms, were the first mass-produced munitions manufactured at Frankford Arsenal. In 1852, the Army constructed a specially designed percussion cap factory, located between the fulminate magazine and the East Storehouse, based upon plans prepared in 1848 by Major Alfred Mordecai and Lieutenant Colonel Rufus Baker. The original plans were modified to incorporate an existing blacksmith shop and reduce construction costs.[14]

The percussion cap factory (Building 38) consisted of the blacksmith shop, a brick building measuring 65 feet by 25 feet, and an ell, similar in size, to the east. A brick hyphen connected the two ells, giving the building a distinctive H-plan, and housed the factory's steam engines, the first steam engines used at the Arsenal.[15] Lathes, a tin shop, and the boilers occupied the west ell, while the east ell housed finishing rooms. Auxiliary structures for the manufacture and storage of fulminate, a magazine, a mixing room, and a drying room were located more than one hundred feet from the main building.[16]

The nitre required for cap manufacturing was stored in a separate building (Building 12), located in a vacant area north of the laboratories and convenient to the Arsenal wharf, the principal means by which raw materials entered the post. Based on a similar structure at Harpers Ferry, this storehouse, like the cap factory, employed an arched wall system that facilitated wagon access. The areas above the spring line were glazed, providing indirect light to the interior.

Building 35, a foundry separate from the cap factory, was erected north of the factory. The structure of this building utilized what Philadelphia's Phoenix Iron Company called

> a very economical combination of iron rafters and wrought iron posts, well adapted for machine shops [and] foundries . . . desirable to cover a large area and also have an ample supply of weight on the floor.[17]

The introduction of manufacturing operations at the Arsenal increased administrative duties and demanded additional office space. The guardhouse southwest of the East Storehouse was converted into offices to partly rectify this situation, replacing the small office that had previously occupied a portion of the Commanding Officer's quarters.[18] An old laboratory or workshop, built in 1836, was subsequently converted into a guardhouse.[19]

By 1857 the Arsenal produced machines to manufacture ordnance, as well as the ordnance itself. The Arsenal's factories also manufactured bags, boxes, tin cases, caps, milling machines, friction tubes, and machines to make friction tubes. In June, 1860, Captain Josiah Gorgas assumed command of Frankford Arsenal. Gorgas initiated experiments in tin and brass cartridge cases and implemented physical improvements to the post. These improvements included work on more than two thousand linear feet of river wall and completion of the Smith Shop (Building 35), located near the Cap Factory. In March, 1861, because of Gorgas' family connections to the South, the Secretary of War relieved Gorgas of his command, despite Gorgas' protests.[20] By June, 1861, the cap and friction tube machinery operated day and night on an essentially wartime schedule.

During the Civil War, Frankford Arsenal greatly increased its efforts to manufacture percussion caps. Other work conducted at the Arsenal included the alteration of muskets, manufacture of gages, repair of shot, and production of small arms ammunition such as paper fuzes and Maynard cartridges.[21]

Colonel T. T. S. Laidley, the post commander during the Civil War, and an expert in the field of ballistics, emphasized construction that would minimize damage caused by explosions. In 1862 a fire, fed by fuzes, burned the Cap Factory to the walls. This incident provoked investigations of new structural designs. Laidley worked closely with the Arsenal's principal private supplier of powder, the duPont Company, to devise a workshop with a wood-sheathed, riveted, wrought iron frame. This laboratory, measuring 53 feet by 23 feet, incorporated a blowout feature intended to lessen the loss of life and property in the event of an explosion. Tests showed that in an explosion, the building's roof and sides would fall, leaving the iron frame intact. This structural principal was used in the complex known as the Laidley Laboratories, constructed east of the Machine Shop. This complex included an ample two-story brick laboratory (Building 57) and a row of shops, placed more than 100 feet from the road, for bundling cartridges.[22] The brick building, focal point and operational center of the complex, measured approximately 59 feet by 55 feet and was flanked by frame wings nearly 34 feet deep. A boiler house, located north of the brick building, housed the complex's steam engine.

Laidley experimented with the use of structural iron in a "fireproof" building. Iron was a major structural element in the Smith Shop, the Cap and Primer Shop, and the Machine Shop (Building 40), as well as in the Rolling Mill, the first plans for which were prepared during Laidley's tour of duty. He also emphasized appropriate construction for a principal magazine, a structure begun in 1864 (Building 240). Laidley's talents were not entirely devoted to construction. He introduced the Schultz chronoscope, for determining the initial velocity of projectiles in the proofing of powder, to the United States Army.[23]

In 1864 Captain Stephen Vincent Benet became commanding officer of Frankford Arsenal.[24] Benet inherited Laidley's wartime construction program, including the Machine Shop, the laboratories, and some housing improvements. The Cap and Primer Machine Shop (Building 40), which Benet saw to completion, was a large brick building with sandstone trim and foundation located south of the Cap Factory complex, east of the planned third square, and west of the Laidley Laboratories. This substantial two-story building was a precursor to the construction techniques, if not the style, of future buildings. The Machine Shop measured 50 feet by 108 feet, with a central rear ell of 54 feet by 40 feet. The building's structure utilized brick vaulting, iron ribs, and wrought iron Phoenix columns that provided

> maximum strength for load bearing duty with a minimum of weight in the column itself [and were] approved as a suitable and convenient post in towers and fireproof structures.[25]

Although it employed new structural principles, the Machine Shop projected the chaste monumentality of the buildings that had preceded it near the Arsenal's first two squares.

Benet proposed that future construction at the Arsenal be standardized in style and function.[26] Benet proposed construction of a two-story, fireproof carpenters' shop located near the Machine Shop. He requested that the building be constructed "in style of architecture, cornice, etc. precisely the same as that of the Machine Shop erected by Maj. Laidley."[27]

During the early days of Benet's command, work began on the largest nineteenth century construction project undertaken at Frankford Arsenal, a Rolling Mill designed to work copper and brass into 12 million cartridge cases per year. The architectural precepts used in the design and construction of this building were largely the product of the Laidley and Benet administrations.[28] The Arsenal administration closely oversaw all aspects of the project, which was built by an in-house workforce, rather than by outside contractors. For three years during the mid-1860s, a workforce of carpenters, bricklayers, masons, painters,

and glazers worked on this and other new buildings, including a Guardhouse (Building 101), and additions to quarters. The Rolling Mill, as originally planned in 1863, was to include machinery for rolling both heated and cold metal and founding brass. The building's machinery was to include 190 draw presses, located on the second floor.[29]

Philadelphia architect John Fraser worked closely with Benet to make the Rolling Mill a functional and architecturally imposing building.[30] Fraser detailed the building in keeping with an overall plan produced by Benet. The Rolling Mill (Building 215) is a large two-story brick building, with a main block that measures approximately 225 feet by 50 feet. It is located near the Arsenal wharf, for the convenient receipt of raw materials. The building originally sat at the southern terminus of a large open space that extended, without obstruction, north as far as the Tacony Street wall. The setting admirably displayed the building's pavilioned front facade. In 1866, the government determined not to equip the building as originally planned. Construction on the project ceased, and the most imposing building on the post was relegated to storage for almost twenty years.

New and more commodious housing was erected at Frankford Arsenal between 1857 and 1870. Existing quarters were enlarged, and a storehouse was converted to residential use. Other buildings were remodeled to accommodate married soldiers who, prior to 1857, had not been provided with quarters on post.[31] The demand for new housing stemmed from the growing size of the post, which by 1868 included sixty enlisted men, eleven of whom were married.[32] In 1870 the old barracks, built at the east end of the first square prior to 1820, was converted for use by families and a new Barracks (Building 23) was erected northwest of the Cap Factory.

In April, 1865, with the end of the Civil War, the production of percussion caps, fuzes, and small arms ammunition largely ceased. This curtailment in production caused approximately one thousand employees to be discharged.[33] In 1866, trials of the one-inch caliber Gatling gun were conducted at Frankford Arsenal, and machinery was constructed to produce the rimfire cartridges used by the weapon.[34]

A wide variety of research and development work was conducted at the Arsenal during the latter part of the nineteenth century. Developmental work included cannon percussion primers, sights, percussion fuzes, paper fuzes, explosive bullets, prismatic powder, Laidley (iron) targets, and precision tools. The Arsenal's testing programs provided data on the strength of cartridge cases under a variety of atmospheric conditions and established standards for providing cartridges of wrapped metal. A new five-hundred-yard firing range was constructed in the marshland located in the northeast section of the Arsenal for ballistics tests.[35]

Both photography and telegraphy were used to record the results of firing range tests.[36]

In 1872, the establishment of a manufacturing plant to produce Woodbridge cannon demonstrated the inadequacy of the Arsenal's transportation connections. The government received the heavy equipment used to manufacture the cannons at a freight siding on the Philadelphia and Trenton line of the Pennsylvania Railroad, six blocks north of the Arsenal, and hauled the equipment to the post by wagon. The Arsenal itself was not served by the railroads, largely because rail companies refused to accept explosive materials for shipment. This situation forced the Arsenal to rely upon water transportation for shipping and receiving raw materials and finished goods. The Frankford Creek wharf continued in use until at least 1912.[37]

In 1881 Charles Lennig, owner of the Tacony Chemical Works, located adjacent to the Arsenal, proposed laying track along the easternmost edge of his property and thence along the river bank to the Arsenal. He secured permission to cross Arsenal property and bridge Frankford Creek so as to provide rail service to his chemical plant from the north and west. Lennig proposed to give the government the privilege of using the track in return for the grant of the right-of-way. The prospect of freight trains traversing the riverfront area of the Arsenal, immediately south of the five-hundred-yard target, prompted the construction, in 1884, of an iron target butt just short of the tracks. Built on a foundation of piles driven to a depth of thirty feet, the butt proper measured 18 feet by 24 feet with extended wings of boiler iron plates that provided a total protective surface of more than 4,700 square feet.[38]

In 1886 the government granted a license permitting the Pennsylvania Railroad to use the Arsenal reservation. The government may have delayed its application for the railroad right-of-way because it considered sparks from a steam engine a potential explosion hazard. In 1889, upon completion of the line to Lennig's works, the Pennsylvania Railroad agreed to extend their tracks from the iron target butt to the Small Arms Cartridge Plant (Building 215) so that the Arsenal could utilize the tracks leading to the Tacony Chemical Works. In order to secure the government traffic, the Pennsylvania Railroad constructed this trackage at its own expense and agreed to strengthen the stone retaining wall built on the mud bottom of the creek, thus providing proper support for its tracks.[39]

The most significant development at Frankford Arsenal during the 1870s and 1880s was the Ordnance Board's 1876 recommendation that the Arsenal be designated as the Army's sole manufacturer of metallic cartridges. Depot and repair operations continued, but after 1876 the production of metallic cartridges became the Arsenal's principal activity.

During the 1880's research activities were discontinued at the Laidley Laboratories. The complex's outbuildings were moved to locations on the periphery of the Arsenal grounds and utilized for a variety of purposes. The main laboratory building and one of the secondary buildings were converted into a new post hospital. The building's accessibility to city water and location away from the center of the post's population, rendered it particularly suitable for the treatment of epidemics and contagious diseases.[40]

Most construction activity at Frankford Arsenal during the 1870s and 1880s involved the erection of small buildings used for ballistics experiments and general storage. The largest projects of the period were the conversion of the Rolling Mill into a small arms cartridge factory and the erection of a Barracks (Building 23), located near Tacony Street, in 1870. This two-story brick building occupied the opposite end of the green from the Rolling Mill.

During the last decades of the nineteenth century, Frankford Arsenal presented a pastoral appearance, possibly reflecting the period of peace following the Civil War. The post grounds were divided into a landscape of formal gardens, parks, and woodlands. Gardens occupied the ground between the Quarters, while the perimeter fencing provided a semblance of seclusion. South of the Carriage and Storehouse (Building 106) were the post's stables, brick buildings erected in 1866. This area also included a number of small outbuildings that defined the post's farmyard area. Cows grazed near the river and in the sections of the post east of the Quarters. The eastern portions of the property continued to be farmed until at least 1870.[41]

During the 1890s, Frankford Arsenal evolved into the nation's center for powder chemistry. The post's depot functions declined in importance throughout this period. Captain John Pitman, who studied chemistry at West Point, became the Arsenal's inspector of powder. Pitman established a new testing program in cooperation with the duPont Company. A former ammunition shed and a storehouse from the old Laidley Laboratory were outfitted with the necessary testing apparatus. A small magazine was constructed a safe distance from the laboratory.

The principal goal of the testing program was to provide a weapon that would succeed in battle. Uniform and precise testing of powders of varying velocities and pressures was required because even slight variations in the preparation of some compositions could produce different ballistic qualities, and because, once in the cartridge, the balance between the powder and the primer charge had to conform to the strictest tolerances.

Pitman's testing program soon resulted in the construction of an improved Proof House in the northeastern section of the Arsenal. The

Proof House featured a 190-foot shooting gallery equipped with two targets and fixed rests. A small laboratory housed testing apparatus while an instrument room contained chronographs. The firing range associated with the Proof House occupied a berm built in the low-lying area between the Principal Magazine and the neighboring property to the east.[42]

Pitman remained at Frankford until May 1898. With him in the laboratory was Lieutenant Beverly Dunn, an Ordnance officer who worked with the Pennsylvania Railroad to facilitate the transportation of explosives by rail, and invented Explosive D (Ammonium Picrate). Dunn remained at Frankford until 1902. His work contributed to the Frankford Arsenal Laboratory's reputation, by 1900, as the premier explosives testing center in the United States. Both governmental and commercial agencies consulted with and used the Arsenal facilities.

In addition to its leadership role in powder chemistry, the Arsenal also became actively involved in the manufacture of precision instruments during the 1890s. This important activity supported the ongoing work on artillery ammunition. Instruments such as the star gauge and other measuring devices for large weapons were fabricated in the old Machine Shop (Building 40).

During the late 1890s, wartime demands associated with the Spanish-American War demonstrated that the Arsenal facilities, which had become fragmented with the introduction of various new tasks and responsibilities, required reorganization to improve efficiency. The huge Rolling Mill housed only a fuze shop and a cartridge bag factory, while the central administrative offices occupied the same small four-room building they had since 1852 (Building 11). In order to consolidate the various facilities manufacturing small arms ammunition, shrapnel, and fuzes, a new cartridge factory was installed in the Rolling Mill, the Arsenal's largest building. This entailed the relocation of several independent shops located in or near the Machine Shop to the Rolling Mill. At this time, the chimney stack south of the building, which had never been completed, was finished.

Most construction work initiated at the Arsenal prior to 1910 was designed to be stylistically compatible with the Rolling Mill. Innovative reinforced concrete structural principals, similar to those used in the Artillery Firing Range butt, were incorporated into the Small Arms Ammunition Storehouse (Building 211), built in 1904 west of the Rolling Mill. The building employed a system of reinforced concrete columns, slabs, and girders to handle loads greatly in excess of customary industrial capacities, but camouflaged these innovations behind a stylistically conservative facade.[43]

During the construction of Building 211, when the reinforced concrete structural system was twenty-eight days old, loading tests were conducted on the structure. With a load of 216,000 pounds, nearly three times the safe live load, the floor girders deflected less than one-half-inch, the elastic limit of the steel reinforcing. Engineers estimated that the floor structure could support a load of 400,000 pounds before absolute failure.[44]

Other new buildings erected at Frankford Arsenal during the first two decades of the twentieth century served the post's new concentration upon the production of high explosives and artillery ammunition. New construction included testing ranges as well as factories. A new Shrapnel Factory (Building 119), erected in 1903, consolidated shrapnel manufacturing operations. Experiments with high explosive shrapnel began in 1909, following construction of a one hundred-yard artillery firing range near the post ice pond. The wooden butts and targets were virtually destroyed in service by 1908, and were replaced with a reinforced concrete structure.[45] By 1909 the high velocity of modern small arms ammunition necessitated construction of a longer testing range and a new 150-foot firing gallery was added to the Proof House. The manufacture of small arms ammunition remained the post's principal activity, as evidenced by the numerous alterations and additions to the cartridge factory. Several large, rather utilitarian buildings were also constructed for storage and manufacturing space. The buildings completed by 1919 were among the last built at the Arsenal for more than two decades.[46]

Research and development work at the Arsenal in the first decades of the twentieth century slowed somewhat with the removal, in 1903, of the work of the chemical laboratory to Sandy Hook Proving Ground in New Jersey, where space existed for the longer ranges required to test artillery. Despite the loss of this facility, chemists at Frankford continued to play an active role in the Army's research and development program, perfecting, in 1906, the first progressive burning powder, a development that revolutionized the manufacture of gunpowder.
The post's Instrument Division began assembling panoramic sights for the Army's three-inch field gun in 1903. Production of panoramic and telescopic sights began in earnest in 1905, and by 1908 the Instrument Division had become a distinct entity at the Arsenal. The Division resulted from the consolidation of the various independent shops involved in this work. Lens grinding began in 1908, and the Optical Shop, which heretofore had been a specialty shop, became part of the Instrument Division. By 1910, the Arsenal, utilizing new facilities housed in the Building 111 and 112 complex, could manufacture optical equipment without outside purchases. Just prior to the United States' entry into World War I the Division achieved a limited degree of standardization and interchangability of optical elements.

During the two peacetime decades between World War I and World War II little construction work took place at Frankford Arsenal. Virtually no mass production of any military ammunition took place during this period. Nevertheless, the Arsenal continued to conduct development projects basic to future production. These projects, which designed and developed new types of ammunition and devised processes for the standardization of both products and manufacturing machinery, enabled the Arsenal to maintain its leadership position. Developmental work conducted during this period included the perfection of new technologies for defense against air attacks. The bomb-sight and ballistics unit sections of the Aircraft Armament Division of the Ordnance Office were transferred to Frankford to assist in the development of a national air defense program.

Departmental reorganization at the Arsenal during the 192Ds and 1930s encouraged the growth of Frankford's research capabilities and facilitated a spirit of cooperation in military/industrial research. The Arsenal furnished private industry with patterns, designs, and formulas intended to assure quality control in the manufacture of government munitions.

The Artillery Ammunition Division maintained current production methods by means of pilot production lines. In the Shell Shop (Building 55), one of the few new industrial structures built during the twenties, Lieutenant Colonel Levin H. Campbell, Jr. (later Chief of Ordnance) established a shell-machinery pilot line. Utilizing the latest principles of production engineering, the line could produce three thousand 75mm shells in an eight-hour day, with only forty-one machine operators. The system became a model for private industry.[47]

In 1938, with the growing threat of war in Europe and an increased potential need of small arms ammunition, the government authorized Frankford Arsenal to procure equipment to manufacture munitions for both the public and private sectors of the industry. These production lines were maintained in operating condition by means of periodic operation within the shops of the Small Arms Ammunition Division.[48]

The increasing importance of .50 caliber ammunition resulted, in 1939, in the relocation of this production line from Building 215 to Buildings 219 and 220. These buildings had been erected in 1909 as the fuze and artillery primer department. The removal of the .50 caliber production line from Building 215 provided additional space for increased production of .30 caliber ammunition.

Following the outbreak of World War II in Europe, the staff at Frankford Arsenal prepared plans for a massive expansion of ammunition production throughout the United States and at the Arsenal. The available floor space of the Small Arms Ammunition Division was expanded by eighty

percent and $7.5 million worth of new machine tools and other equipment were purchased to increase capacity. The Arsenal continued to function as the sole manufacturer of military ammunition in the United States until the private sector completed the equipping and tooling of civilian plants.

The Arsenal staff worked closely with the civilian munitions industry in the months prior to the United States' entry into World War II. In the summer of 1940 the Ordnance Department initiated action to create a vast interlocking network of ammunition facilities owned by the government and operated by private industry. Between June 1940 and December 1942, more than sixty government owned-contractor operated (GOCO) plants were constructed.[49] Frankford Arsenal provided technical assistance and training to the private firms operating these facilities.

Frankford Arsenal's mission during World War II was the manufacture and development of small arms ammunition, artillery projectiles, cartridge cases, optical and fire control instruments, gauges, and pyrotechnics. With the onset of the war, Frankford shouldered the burden of the country's ammunition production while the private sector geared up. The proliferation of different ammunition calibers and types, each requiring its own production line, put work space at a premium. It also forced an expansion program that resulted in the conversion of older buildings to new uses and that ultimately doubled the number of structures on the post. Buildings 227 and 229, constructed in 1941, housed the production line for the newly developed .30 caliber incendiary cartridges. Other new buildings housed manufacturing shops and storage and distribution activities.[50]

The accelerated expansion of the Arsenal's ammunition production facilities placed a great strain on the post's existing utility system. In May 1943 the government expanded the Arsenal property by acquiring, through eminent domain, the 8.8-acre tract of the Edwin H. Fitler Company, adjoining the Arsenal to the east.[51] The remains of the Fitler Cordage Company's buildings were destroyed and a series of small buildings (Buildings 400-439) were hastily erected for use in mixing, drying, and storing highly volatile materials.

The wartime footing of the Arsenal greatly increased the size of the work force. The Civil Service Commission cooperated in the buildup by granting the Frankford staff permission to hire employees based upon their suitability for the work, rather than upon past experience. Women filled many of the new job openings, particularly in the Small Arms Ammunition Division, which increased by forty-four percent during 1941.[52] The Small Arms Ammunition Division, operated around the clock, seven days a week, producing nine million cartridges per day. This represented six percent of the entire demand for ammunition during World War II.[53]

The Artillery Ammunition Division reached maximum production in October 1942, when a total of 5,492 tons of finished components were shipped. In less than two years, shell production had increased from 40,355 to 75,852 per month, cartridge case production from 54,841 to 1,684,356 per month, and mechanical time fuze production from 29,025 to 252,774 per month.[54] The manufacture of ammunition at Frankford Arsenal during World War II was concentrated in the shops along Craig Road, one of four continuous east-west streets at the Arsenal.

Throughout World War II, research and development continued to be conducted at Frankford Arsenal. This program resulted in the construction of Building 64, now known as the Pitman-Dunn Laboratory. Major efforts were made to conserve rare materials or to develop substitutes. The Laboratory initiated a Steel Case Program to substitute steel for brass in the manufacture of cartridge cases. In cooperation with the Evansville (Indiana) Ordnance Plant, Frankford successfully developed a steel case for the .45 caliber cartridge that, after thorough testing, became standard issue. This success led to efforts to adapt steel cartridge cases to the production of .30 and .50 caliber ammunition. Ultimately, steel cases were utilized in the manufacture of ammunition of various calibers and types. The savings in brass effected by this innovative program totaled 1,774 pounds per 100,000 rounds of ammunition.

Material savings became relatively unimportant, however, after May 1943, when a surplus of ammunition developed. This surplus, which resulted from extraordinary production efforts and lower than anticipated combat expenditures, caused a drastic curtailment of the steel case program. By November 1943, work on the .30 and .50 caliber steel cases had halted, although experimental production continued.[55]

Possibly the most significant piece of research and development to emerge from Frankford Arsenal during World War II was the recoilless rifle. Ordnance designers had worked for years to eliminate heavy recoil-absorbing mechanisms from conventional artillery pieces. The Arsenal staff, using the post facilities, as well as working in the privacy of the home of Dr. William J. Kroeger, a staff physicist, developed a new concept for the construction of breeches and cartridge cases in less than six weeks. The resulting weapon, a 57mm cannon dubbed the M-18 Kro-Musket, weighed only forty-four pounds.[56]

The weapon achieved a recoilless effect by venting the propellant gases through the breech. This necessitated special cartridge cases with perforated walls that directed the gases rearward, resulting in a rearward blast equal to that of the forward thrust, thus canceling out the normal recoil of the gun. The recoilless rifle proved especially effective against tanks, pillboxes, and caves. The rear blast of the

weapon prevented it, however, from being used in a confined area and betrayed its position to the enemy.

In March 1945, as the end of the war approached, overall production requirements at Frankford Arsenal were reduced by approximately twenty percent. In May, following Germany's surrender, production goals were further cut, as civilian production of military ammunition ceased. Two weeks after the Japanese surrender in August 1945, production halted at all United States facilities except Frankford Arsenal, where production of experimental ammunition types continued. Frankford's work force was gradually reduced to a complement of 6,850. By the end of 1945, Frankford Arsenal had again become the sole producer of military ammunition in the United States. The Arsenal returned to its pre-war role of maintaining "those phases of the munitions art that do not have a commercial counterpart."[57]

After the end of World War II, Frankford Arsenal staff again concentrated upon research and development projects. In August, 1945, the Arsenal staff began work on the development of an escape system for the pilots of jet aircraft. The speed of jet aircraft required a special ejection system that would carry the pilot away from the aircraft quickly and safely. In 1947, after an intensive research and engineering effort, the Arsenal tested the world's first catapult ejection system. The innovative feature of this system was the propellant-actuated device, or PAD, a compact self-contained component that utilized the energy of gas produced by burning propellants to trigger a mechanical action that ejected the pilot and his seat. Frankford Arsenal staff ultimately developed all of the cartridge-actuated devices used by the United States Air Force.[58]

In 1947, the Fire Control Design Division and the Instrument Division combined to form the Fire Control Instrument Department. This administrative reorganization stimulated ongoing research into questions of fire control. This work was conducted in shops located in Buildings 45 and 46, originally erected in 1919, and Buildings 111 and 112, which dated to the turn of the century.

During the Korean War, the pace of production at the Arsenal again quickened, sparking the construction of more than thirty temporary structures, mostly located in the southeastern section of the property. In 1951, the government obtained the remaining property of the Fitler Cordage Company, the last land acquisition associated with the Arsenal.[59] The major buildings on this tract were converted to Arsenal use, rather than being razed in favor of new construction.[60]

The close-in fighting that characterized Korean War combat required light weapons and ammunition effective at short ranges. The Arsenal developed and tested new types of munitions designed to meet these

needs. Testing took place in the largest building ever constructed at Frankford Arsenal, the Small Arms Ammunition Proof House (Building 521), completed in 1954 at the far eastern edge of the property. The Proof House was used for a variety of NATO-sponsered experiments from 1960 to 1975.

In August 1962, following a reorganization of the Army, Frankford Arsenal became headquarters for the Army Ordnance Special Weapons Ammunition. Research and development work focused upon fire control devices, artillery cartridge cases, time fuzes, and propellant-actuated devices. Pilot manufacturing activities were restricted to the production of small arms ammunition of less than 20mm. Pure research continued in the fields of metallurgy, mycology, optics, corrosion, and lubricants.[61] In the following years, development projects included a cannon artillery digital computer adapted for fire direction.[62]

After 1975, the reorganization of the Army altered the role of the Arsenal and closure of the post became imminent. Frankford Arsenal ceased to function as an active facility in 1976, with operations transferred to other installations.[63]

With the exception of the site and its extant buildings, the tangibles of Frankford's history have been dispersed. What remains is the contained environment that stands in mute testimony to a unique military history. The property, enclosed as it is by walls and waterways, constitutes a resource that clearly conveys the entire history of military munitions from the blackpowder days of the early Republic to the modern lasers and other electronic devices. Many of the buildings served several functions, and are of consequence only as part of the whole, while others are architectural or historical landmarks in their own right. In its entirety, Frankford Arsenal comprises an entity that made singular contributions to the technological development of the United States far beyond its limited military mission.

NOTES

[1]Act of May 14, 1812 -- 2 Stat. 732.

[2]Act of February 8, 1815 -- 3 Stat. 203.

[3]Alfred T. Mahan, Sea Power in its Relations to the War of 1812 (Boston, 1905).

[4]J. Rees to Colonel G. Bomford (September 21, 1815), Letters Received, Office of the Chief of Ordnance, Record Group (RG) 156, National Archives, Washington, D.C. Unless otherwise noted, all official correspondence is from the records of the Office of the Chief of Ordnance (OCO), Record Group 156 at the National Archives, Washington, D.C.

[5]Colonel W. Linnard to Bomford (December 24, 1815), Entry 43, Orders, June 1815 -- November 6, 1818, Records of the Quartermaster General, RG 74, National Archives, Washington, D.C.

[6][Robert Burns], "Record of the Medical History of the Post," (U. S. Army Medical Department, ca. 1872), p. 2 -- hereafter cited as "Medical History"; Thomas Martin to Bomford (February 28, 1821).

[7]Rees to Bomford (June 8, 1816).

[8]Rees to Colonel D. Wadsworth (December 6, 1816).

[9]Linnard to Wadsworth (March 9, 1819).

[10]Martin to Bomford (July 29, 1821); Ibid. (September 4, 1821).

[11]Major A. Mordecai to Bomford (June 5, 1835).

[12]Mordecai to Bomford (July 3, 1835).

[13]Berkley Lewis, Small Arms and Ammunition in the U. S. Service (Washington, 1956), p. 168.

[14]The plan is described in Arsenal reports but the document is not extant.

[15]Major P. Hagner to Colonel H. K. Craig (May 23, 1852).

[16]Lieutenant Colonel R. L. Baker to Craig (January 13, 1852).

[17]Phoenix Iron Company, Useful Information for Architects and Engineers Working in Wrought Iron (Philadelphia, 1890), p. 44.

[18]Hagner to Craig (April 28, 1854).

[19]Henry D. K. Muhlenberg, "The Frankford Arsenal, History" (1913), p. 33 -- Typescript on file at Rock Island Arsenal, Rock Island, Illinois.

[20]Captain J. Gorgas to Craig (March 22, 1861); Gorgas to War Department (March 25, 1861). For a biography of Gorgas, later Confederate Chief of Ordnance and father of Dr. William Gorgas, of Panama Canal fame, see Frank E. Vandiver, Ploughshares into Swords (Austin, 1962).

[21]Muhlenberg "Frankford Arsenal" (1913), p. 41.

[22]"Laboratory" in the English sense is the place where primer compositions and fulminate of mercury are handled and produced.

[23]See S. V. Benet, Electro-Ballistic Machines and the Schultz Chronoscope (New York, 1866) for information on this sensitive machine.

[24]Benet was grandfather of the poet and father of Colonel J. Walker Benet, commander of Augusta Arsenal from 1911 to 1919. He had formerly served as a junior officer at Frankford under Hagner.

[25]Phoenix Iron Company, Useful Information (1890), p. 92.

[26]Benet to Dyer (November 2, 1864).

[27]Ibid. (March 13, 1865).

[28]Ibid. (September 23, 1864).

[29]Colonel T. T. S. Laidley to Ramsay (December 26, 1863).

[30]Fraser designed government buildings in the 1860s when civilian construction slowed. Fraser opened his practice in 1854, working alone until 1858 when he formed a partnership with civil engineer Andrew Palles. In 1863, apparently working alone, he designed the Union League Building on South Broad Street in Philadelphia, a building that shares many design features with the Rolling Mill, especially its use of brick with red sandstone detail and corbeling. In 1868 Fraser was a partner in the firm of Fraser Furness and Hewitt. His partners were George Hewitt, who had studied with John Notman, and Frank Furness, who had worked in the studio of Richard Morris Hunt, the first American-born student at the Ecole des Beaux Arts in Paris.

[31]Hagner to Craig (May 18, 1857).

[32]Burns, "Medical History" (ca. 1872).

[33]Muhlenberg, "Frankford Arsenal" (1913), p. 40.

[34]Paul Wahl and Donald Toppell, The Gatling Gun (New York, 1965), pp. 28-35.

[35]The firing range emphasized the lack of space at Frankford. Cannon projectiles were liable to escape from the butt and fall into the Delaware, challenging nearby boatmen and fishermen.

[36]Treadwell to Dyer (April 18, 1870).

[37]Report of Chief of Ordnance (1875-1876), p. 160; Henry Muhlenberg, "A History of Frankford Arsenal," in History of Arsenals, Augusta, Benicia, Frankford, New York, Picatinny (1912), p. 2. Typescript on file in RG 156, National Archives, Washington, D.C.

[38]Muhlenberg, "Frankford Arsenal" (1913), p. 55.

[39]Ibid., p. 63; Report of Chief of Ordnance, 1881, Appendix 12 (Washington: Government Printing Office, 1881), p. 81.

[40]Major L. D. Lyford to Benet (March 10, 1883), Quartermaster Consolidated File, Box 314, Records of the Office of the Quartermaster General, RG 92, National Archives, Washington, D.C.

[41]Burns, "Medical History" (ca. 1872); Muhlenberg, "Frankford Arsenal" (1913), p. 38.

[42]Ordnance Report, 1893, Appendix 16 (Washington: Government Printing Office, 1893), pp. 275-277.

[43]John Milner Associates, "Historical and Archeological Survey of Frankford Arsenal, Philadelphia, Pennsylvania" (West Chester, Pennsylvania 1979), pp. 190-193. Typescript report prepared for the Department of the Army, Baltimore District Corps of Engineers. Copies on file at the Historical Society of Pennsylvania and the Philadelphia Historical Commission.

[44]Colonel F. Heath, "Report of Principal Operation" (July 10, 1905), Box 1059, RG 156, National Archives, Washington, D.C.

[45]Milner Associates, "Frankford Arsenal" (1979), p. 189.

[46]The High Explosives Loading Shop (Building 123) and the Small Arms Ammunitions Structure (Building 211) are examples of buildings constructed during this period.

[47]Levin H. Campbell, Jr., "Artillery Ammunition Production," Army Ordnance, 19 (March--April 1939), pp. 273-276; "Cartridge Case Manufacture," Army Ordnance, 20 (January--February 1940), pp. 239-243; "Armament Production: A Study of Ordnance Engineering Policies," Army Ordnance, 21 (November--December 1940), pp. 221-234.

[48]Harry C. Thomson and Linda Mayo, The Ordnance Department: Procurement and Supply (Washington, 1960), p. 22.

[49]Ibid., p. 105.

[50]Typical are the completion, in 1941, of Buildings 201-202 in the southwest corner of the Arsenal, which served as offices and a storehouse, respectively, and Building 235, at the east end of Craig Road, which functioned as an artillery ammunition planning room and fuze shop. Ancillary structures included Buildings 124, 125 and 126, which functioned as service shops. More than 80 other structures were built during this period.

[51]Philadelphia Deed Book, CJD 234, p. 93 (May 24, 1943).

[52]Frankford Arsenal, "Research, Development, and Production of Small Arms Ammunition, 1919-1944," pp. 48, 113. On file at Rock Island Arsenal, Rock Island, Illinois. At the height of the war 22,000 people were employed at the Arsenal. Building 107 was constructed in 1941 to provide the office space required to administer this rapid expansion. The building occupied an open green space that had survived since 1870.

[53]Frankford Arsenal, "Historical Highlights, U. S. Army Munitions Command" (Frankford Arsenal, ca. 1971), p. 5.

[54]Eva Adair, "Frankford Arsenal" (1950), p. 1. On file at Rock Island Arsenal, Rock Island, Illinois.

[55]Constance McLaughlin Green, Harry C. Thomson and Peter C. Roots, The Ordnance Department: Planning Munitions for War (Washington, 1955), pp. 492-3.

[56]For further material on this weapon, see "Kickless Cannon," Time (July 23, 1945), p. 25; Ibid. (July 29, 1945), pp. 53-54.

[57]Thomson and Mayo, The Ordnance Department (1960), p. 474.

[58]Frankford Arsenal, "Facilities and Functions of the Arsenal," (1956), pp. 29, 90. On file at Rock Island Arsenal, Rock Island, Illinois.

[59]Philadelphia Deed Book DJP 3054, p. 441 (August 15, 1951).

[60]The Fitler buildings are no longer extant.

[61]Frankford Arsenal, General Orders (August 14, 1961).

[62]Frank E. Comparato, Age of Great Guns (Harrisburg, 1965), p. 312.

[63]Frankford Arsenal Caretakers' Activity, "Annual Historical Report," (1976).

BIBLIOGRAPHY

The background research and building-specific research required to produce this Historic American Engineering Record (HAER) documentation was conducted by John Milner Associates, Inc. under a prior contract in 1979. That work resulted in a report, prepared for the Department of the Army Baltimore District, Corps of Engineers. The full citation for this report is:

John Milner Associates, "Historical and Archeological Survey of Frankford Arsenal" (West Chester, PA: John Milner Associates, 1979). Report prepared for the Department of the Army Baltimore District, Corps of Engineers, Baltimore, Maryland.

Copies of this document are on file at the Historical Society of Pennsylvania, the Free Library of Philadelphia, and the Philadelphia Historical Commission.

The 1979 study includes extensive footnotes and a twenty-three page Bibliographic Essay (pp. 374-397). This essay lists in detail the various collections and sources used by John Milner Associates to compile the report.

The historical narrative portion of this HAER documentation is a condensed version of the "History" section of the 1979 report (pp. 2-87). No new research was conducted as part of this recordation project. Building specific data was also compiled from information contained in the 1979 report.


MAP OF THE FRANKFORD ARSENAL
FF - 12958
TACONY STREET
BRIDGE STREET